SYNTHESIS OF INDIUM ZINC OXIDE VIA SOL GEL METHOD AS CONDUCTIVE FILLER

This report is submitted in accordance with requirement of the University Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering with Honors.

by

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2019

DECLARATION

I hereby, declared that this dissertation entitled “synthesis of indium zinc oxide via sol gel method as conductive filler” is the result of my own research except as cited in references.

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for the degree of Bachelor of Manufacturing Engineering (Hons).
The members of the supervisory committee are as follow:

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ABSTRACT

Electromagnetic Interference (EMI) is a problem that occurs in electronic world due to increased availability of electronic devices and needs to be overcome. To solve this problem, EMI shielding has been designed using conductive or magnetic materials to block the EMI. Metals are common materials used to make EMI shielding but due to its high corrosion and assembly cost, new materials are being developed to replace metals. This project aims to synthesize indium zinc oxide (IZO) powder that can be used as filler in polymer composite to replace the use of metal as EMI shielding. The IZO powder was formed by using the sol-gel method. In this study IZO particles synthesized via sol gel method at different doping concentration and annealing temperature were characterized, and effects of indium doping and annealing temperature on electrical properties of IZO particles were studied. The concentration of indium doping was varied at 0%, 3%, 5% and 7% for the same annealing temperature of 200 °C. Another set of parameter of samples was 5% indium concentration with different annealing temperatures of 80, 200, 300 and 450°C. The IZO particles were characterized using scanning electron microscope (SEM), energy dispersive x-ray (EDX), x-ray diffraction (XRD) and Fourier transform infrared spectroscopy (FTIR). For the conductivity test, 4 point-probe test was used. From the result obtained, the concentration of different indium percentages does effect the conductivity of the IZO particles and the annealing temperature also affect the microstructure of IZO particle, in which the particle size became smaller when higher temperature was applied. Annealing temperature also affects the conductivity of IZO particle, in which the conductivity of IZO increase with the increase of annealing temperature.

ABSTRAK

Gangguan Elektromagnetik (EMI) adalah masalah yang berlaku di dunia elektronik disebabkan peningkatan ketersediaan peranti elektronik dan perlu diatasi. Untuk menyelesaikan masalah ini, perisai EMI telah direka bentuk menggunakan bahan konduktif atau magnet untuk menyekat EMI. Logam adalah bahan biasa yang digunakan untuk melindungi perisai EMI tetapi disebabkan kos kakisan dan perakitan yang tinggi, bahan-bahan baru sedang dibangunkan untuk menggantikan logam. Projek ini bertujuan untuk mensintesis serbuk indium zink oksida (IZO) yang boleh digunakan sebagai pengisi komposit polimer untuk menggantikan penggunaan logam sebagai perisai EMI. Serbuk IZO dibentuk dengan menggunakan kaedah sol-gel. Dalam kajian ini, zarah-zarah IZO yang disintesis melalui kaedah sol gel pada kepekatan doping yang berbeza dan suhu penyepuhlahan dicirikan, dan kesan doping indium dan penyepuhlindapan pada sifat elektrik zarah IZO telah dikaji. Kepekatan doping indium berubah-ubah pada 0%, 3%, 5% dan 7% untuk suhu penyepuhlahan yang sama 200 ° C. Satu lagi parameter sampel adalah 5% kepekatan indium dengan suhu penyepuhlahan yang berlainan sebanyak 80, 200, 300 dan 450 ° C. Zarah IZO dicirikan dengan menggunakan mikroskop elektron pengimbasan (SEM), sinaran penyebaran tenaga (EDX), difraksi sinar-X (XRD) dan Transformasi empatier spektroskopi inframerah (FTIR). Bagi ujian kekonduksian, ujian 4 titik-probe telah digunakan. Dari hasil yang diperoleh, kepekatan peratusan indium yang berlainan memberi kesan kepada kekonduksian zarah IZO dan suhu penyepuhlindapan juga mempengaruhi struktur mikro zarah IZO, di mana saiz zarah menjadi lebih kecil apabila suhu yang lebih tinggi digunakan. Suhu penyerapan juga mempengaruhi kekonduksian zarah IZO, di mana kekonduksian IZO meningkat dengan peningkatan suhu penyepuhlindapan.

.

DEDICATION

My beloved father, Wan Omar
My appreciated mother, Che Rokiah
My adored sisters and brothers
For giving me moral support, money, cooperation, encouragement and also understandings Thank You So Much & Love You All Forever

ACKNOWLEDGEMENT

In the name of ALLAH, the most gracious, the most merciful, with the highest praise to Allah that I manage to complete this final year project successfully without difficulty.

My respected supervisor, Dr. Mohd Edeerozey Bin Abd Manaf for the great mentoring that was given to me throughout the project. Besides that, I would like to express my gratitude to my mentor, Mrs. Nurhernida as well as to all UTeMs' technicians for their kind guidance in helping me to use the equipment in the faculty lab.

Last but not least, I would like to give a special thanks to my friends who give me much motivation and cooperation mentally in completing this report. I am, thankful for their suggestion and comments throughout my research. Thanks for the great friendship.

Finally, I would like to thank to everybody who has contributed to this FYP report, as well as to express my apology that I could not mention personally each one of you.

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LIST OF ABBREVIATION

EMI	-	Electromagnetic Interference
RFI	-	Radio Frequency Interference
AC	-	Alternating Current
DC	-	Direct Current
ZnO	-	Zinc Oxide
IZO	-	Indium Zinc Oxide
ITO	-	Indium Tin Oxide
SEM	-	Scanning Electron Microscopy
EDX	-	Energy Dispersive X-Ray
XRD	-	X-Ray Diffraction
FTIR	-	Fourier Transform Infrared Spectroscopy
FED	-	Field Discharge

CHAPTER 1

INTRODUCTION

This chapter covers brief background, problem statements, and objectives to be achieved through the study, scope of the study and significance of study.

1.1 Background of study

Electromagnetic interference (EMI), likewise called radio-frequency interference (RFI) when in the radio frequency spectrum, is an unsettling influence created by an outer source that influences an electrical circuit. The unsettling influence may debase the execution of the circuit or even prevent it from working. On account of an information way, these impacts can extend from an expansion in mistake rate to an aggregate loss of the information. Changing of electrical current and voltage from men made and natural resources can also lead to EMI. EMI is a twisting on an alternate current (AC) or direct current (DC) line sent through the conductive way of a circuit. At the point when the area of an electromagnetic field is in the radio frequency go with another electronic device, the EMI intrusion happens. EMI fields can be created by immediate and powerful remote transmitter which can disturb the activity of electronic close-by.

Electromagnetic Interference can emerge from various perspectives and from various sources. The distinctive kinds of EMI can be arranged in various ways. Man-made EMI for the most part emerges from different hardware circuits, albeit some EMI can emerge from exchanging of huge flows. From natural causes, this kind of EMI can emerge from numerous sources, for example, astronomical clamor and also lightning and other environmental sorts of commotion all contribute. Continuous interference is an EMI for the most part emerges from a source, for example, a circuit that is emitting a continuous signal. Anyway foundation commotion, which is ceaseless might be made in various ways, either synthetic or normally happening. Impulse noise, this kind of EMI might be man-made or normally happening. Lightning, and exchanging frameworks all add to motivation commotion which is a type of EMI.

All the electronic equipment must work with a good electrical ground system to maintain a strategic distance from issues that happen as a result of EMI. Circuit design isn't sufficient to secure against over the top dimensions of electromagnetic radiation from the equipment or impacting the rigging. Electromagnetic shielding is an elective that is typically used as a piece of these cases. Electromagnetic shield can work in the two headings which are blocking surges from the equipment and blocking electromagnetic radiation that may impact the unit. EMI shielding is known to be made for the most part from metal, which is known to have great mechanical and electrical properties. Be that as it may, metal is normally powerless to erosion issue, high thickness and high assembling expense.

Due to the properties and disadvantages of metal materials as EMI shielding, new alternatives and methods are carried out to develop the EMI shielding. One of the alternative is by the use of composite as a replacement for the use of metals in making EMI shielding. In composite world, the use of natural fibres as a reinforcement and polymer as matrix in composite structure are widely used as they provide lots of benefits and comparable mechanical properties compared to the use of metals. In order to increase the conductivity of this composite, conductive filler is added in the process of making composite.

Conductive material such as Zinc Oxide (ZnO) was used as a conductive filler in the making of composite. ZnO is a material that well known for its conductivity and high transparency as proven made by previous studies. Zinc Oxide possesses a unique position among materials owing to its superior and diverse properties such as piezoelectricity, chemical stability, biocompatibility, optical transparency in the visible region, high voltage current nonlinearity (Mujdat Caglar, 2009). To increase and improve the conductivity of ZnO more significantly, indium was used as dopant in making the preparation of ZnO by using the sol gel method.

1.2 Problem Statement

EMI shielding materials have been made for the most part from metal, which is known to have great mechanical and electrical properties. Be that as it may, metal is ordinarily helpless to erosion issue, high thickness and high assembling expense. Electromagnetic interference (EMI) shielding is turning into a more essential issue as electronic gadgets turned out to be all the more broadly utilized in our living surroundings and additionally in mechanical and restorative fields. With the end goal to be utilized as EMI shielding, a material requires certain level of electrical conductivity. Adding conductive filler is a technique that can be used to expand the electrical conductivity of characteristic composite.

Indium zinc oxide (IZO) doping is liked to be one of the strategies to enhance the electrical conductivity of composite. IZO covering is picked in light of the fact that contrasted with regular utilized indium tin oxide (ITO). Plus, indium zinc oxide is viewed as good with polymer composite because of its low handling temperature that makes it reasonable fir low debasement temperature of fibres.

1.3 Objectives

The purpose of this research are:

a) To synthesizes indium zinc oxide (IZO) particle via sol gel method.
b) To characterize the indium zinc oxide particle prepared at different doping concentration and annealing temperature.
c) To study the effects of indium doping and annealing temperature on electrical properties of indium zinc oxide particle.

1.4 Scope of Research

The scopes of research are:

a) The study on synthesis of Indium Zinc Oxide particle via sol gel method.
b) The study on the effect of annealing temperature on electrical and microstructure of Indium Zinc Oxide particle.
c) The study on the effect of Indium doping concentration on electrical properties at different annealing temperature.
d) The study on characteristic of elemental crystal structure and microstructure of Indium Zinc Oxide particle.

1.5 Important of Study

Nowadays the use of electronics devices are widely around the world, without EMI shielding materials the electronic devices will have the tendency to get interrupted by the EMI. Hence, the study carried to produce EMI shielding material using conductive material such IZO as filler in composite is one of the way to produce EMI shielding by lowering the cost of manufacturing and reduce the use of metals in making the EMI shielding. As known metals are materials that have erosion issues and high assembling cost that need to be replaced to a better material.

CHAPTER 2

LITERATURE REVIEW

2.1 Zinc Oxide

Zinc Oxide is an inorganic compound that is insoluble in water. The formula for Zinc Oxide is ZnO. It exists in the form of white powder. Zinc oxide (ZnO), a wide bandgap (3.4 eV) II–VI compound semiconductor, has a stable wurtzite structure with lattice spacing a = 0.325 nm and c = 0.521 nm (Lu, 2005). Unique properties that exhibit in ZnO such as good electrical, structural and optical properties have attracted lots of researcher to carry on experiment and utilize these unique properties to improve or develop new beneficial products. Figure 2.1 shows the physical properties wurtzite of ZnO. The scientific research was pulled in towards this material because of its different surprising electrical, basic and optical properties.

Properties	Value
Lattice constants ($T = 300$ K)	
a_0	0.32469 nm
c_0	0.52069 nm
Density	5.606 g/cm^3
Melting point	2248 K
Relative dielectric constant	8.66
Gap Energy	3.4 eV, direct
Intrinsic carrier concentration	$<10^6$ cm^{-3}
Exciton binding energy	60 meV
Electron effective mass	0.24
Electron mobility ($T = 300$ K)	200 cm^2/Vs
Hole effective mass	0.59
Hole mobility ($T = 300$ K)	5–50 cm^2/Vs

Figure 2.1: Physical properties of wurtzite ZnO (Lu, 2005).

2.1.1 Crystal Structure of Zinc Oxide

Zinc Oxide is a wide gap semiconductor, ZnO is a long known and versatile II-VI compound semiconductor with a wide band gap of 3.44 eV, and is widely used in electronics, photonics, acoustics and sensing (Sheen-Jeff Teh, 2014). For instance, the wide band gap and simple doping procedure make this material a decent decision for different optoelectronics applications. This material additionally shows piezoelectric properties which further opens the entryway for different innovative applications The greater part of the group II–VI binary compound semiconductors take shape in either cubic zinc blende or hexagonal wurtzite (Wz) structure where every anion is encompassed by four cations at the sides of a tetrahedron, and the other way around. There are three types of crystal structure shared by ZnO as wurtzite, zinc blende, and rock salt. Wurtzite symmetry exist only in stable phase of thermodynamically under the ambient conditions. The zinc-blende ZnO structure can be stabilized only by growth on cubic substrates and the rock salt (NaCl) structure may be obtained at relatively high pressures (Bakhtiar Ul Haq, 2013). Figure below shows the structure of zinc oxide.

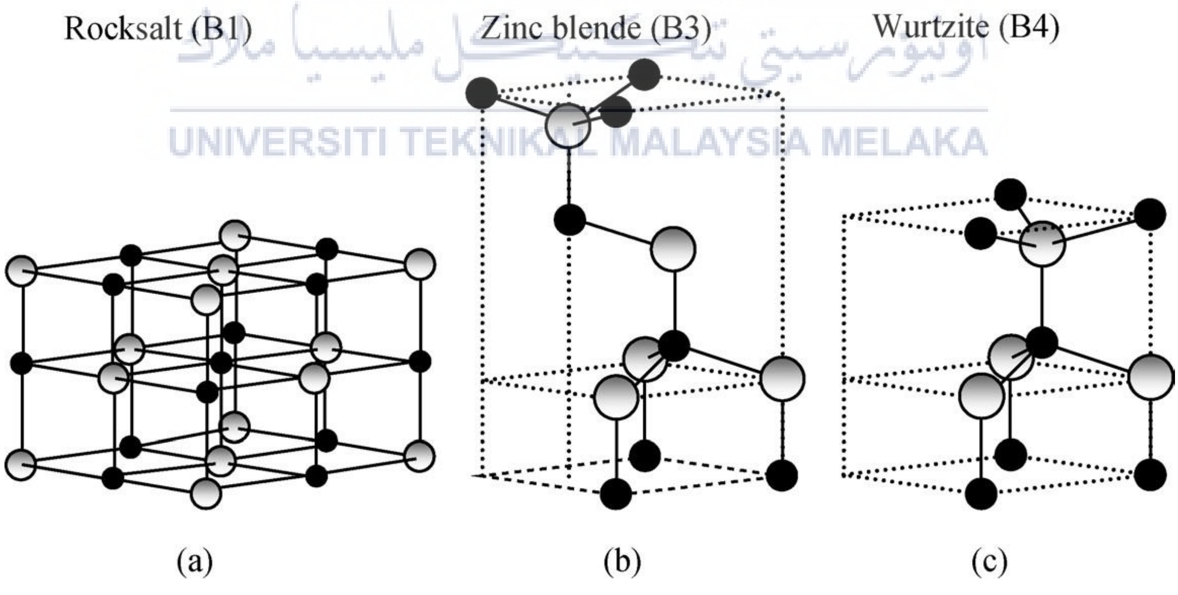

Figure 2.2: Shows (a) cubic rocksalt (B1), (b) cubic zinc blende (B3), and (c) hexagonal wurtzite (B4). Shaded grey and black spheres denote Zn and O atoms, respectively (Özgur, 2009).

Wurtzite zinc oxide has a hexagonal structure with lattice parameters a = 0.3296 and c = 0.520 65 nm, the structure of ZnO can be simply described as a number of alternating planes composed of tetrahedrally coordinated O^{2-} and Zn^{2+} ions, stacked alternately along the c-axis (Wang, 2004). This tetrahedral coordination is common of sp3 covalent bonding nature; however, these materials additionally have a significant ionic character that will in general increment the band hole past the one anticipated from the covalent holding. ZnO is stable thermodynamically with the wurtzite phase due to its ionicity that resides exactly at the borderline between the covalent and the ionic materials (Jagadish, 2007).

2.1.2 Electrical properties of Zinc Oxide

As an immediate and wide bandgap material, ZnO is drawing in much consideration for an assortment of electronic and optoelectronic applications. Points of interest related with an enormous bandgap incorporate high-temperature and high-control activity, lower noise generation, higher breakdown voltages, and capacity to support huge electric fields. Transportation of electron in semiconductor considered to be low electric field and high electric field.

At adequately low electric fields, the vitality picked up by the electrons from the connected electric field is little contrasted with the warm vitality of electrons what's more, in this way the vitality circulation of electrons is unaffected by such a low electric field. At the point when the electric field is expanded to a point where the vitality picked up by electrons from the outer field is never again immaterial contrasted with the warm vitality of the electron, the electron circulation capacity changes altogether from its equilibrium value. The high electron mobility, high thermal conductivity, wide and direct band gap and large exciton binding energy make ZnO suitable for a wide range of devices, including transparent thin-film transistors, photodetectors, light-emitting diodes and laser diodes that operate in the blue and ultraviolet region of the spectrum (Walle, 2009).

Table 2.1: Electrical Properties of ZnO

Electron effectiveness mass	0.28
Hole effective mass	1.8
Electron Mobility (300 K)	205 cm^{-2}
Hole mobility (300 K)	180 cm_{-2} $V_{-1}S_{-1}$
Saturation electron drift velocity	10^7 cm/S
Static dielectric constant	8.47
	1.2 C/m^2

2.1.3 N- and P- Type of doping Zinc Oxide

Despite the ongoing fast advancements, controlling the electrical conductivity of ZnO has remained a noteworthy test. While various research gatherings have revealed accomplishing p-type ZnO, there are still issues concerning the reproducibility of the outcomes and the dependability of the p-type conductivity. Indeed, even the reason for the normally watched accidental n-type conductivity in as-developed ZnO is still under discussion.

The main issues about ZnO is always about controlling the conductivity about ZnO. This is because even relatively small percentages concentrations of native point of defects and impurities (down to 10−14 cm^{-3} or 0.01 ppm) can significantly will affect the properties of electrical and as well as the optical properties of semiconductors (Walle, 2009). Hence, conductivity of ZnO can be controlled by understanding the incorporation of impurities and the role of native point defect. The unintentional n-type of conductivity of ZnO is commonly because the reason would be identified with the accidental fuse of contaminations that go about as shallow benefactors. For example, hydrogen which is available in practically all development and handling situations. By methods of density estimations, it has been appeared interstitial H shapes a solid bond with O in ZnO and goes about as a shallow giver, as opposed to the amphoteric conduct of interstitial H in conventional semiconductors.

Acquiring p-type doping in ZnO has demonstrated to be an extremely difficult assignment. One reason is that ZnO has an inclination toward n-type conductivity, and advancement toward understanding its causes is fairly recent. ZnO has a shallow contributor level, in this way, could be the potential sources for the accidental n-type conductivity. On the other hand, these low energy intrinsic defects could be responsible for the equilibrium p-type doping difficulties of ZnO (C. H. Park, 2002). The exchange of dopants, polluting influences, and natural deformities is crucial for the electrical and optical properties of ZnO, particularly in the event that one might want to accomplish p-type conductivity. In an ongoing methodology for p-type doping by repeat temperature moodulation development it has been demonstrated exemplarily high quality crystal growth development and doping with nitrogen must be done in rather different temperature routines. Then again, particle implantation with nitrogen into industrially accessible ZnO single precious crystal and consequent thermal annealing has likewise been shown to result in the formation of a p-n junction and electroluminescence.

The creation of semiconductor devices is mainly based on ion implantation as a primary step to create p-n junctions because this method allows tailoring their depth in the material and geometrical structure in accordance with industrial production needs (G Brauer, 2011). To achieve p-conductivity, doping of ion will be considered. It has been discovered that with gathering I dopants alone, substitutional acceptors are for the most part self-compensated by interstitial benefactors, while in ZnO co-doped with H debasements, the arrangement of compensating interstitials is seriously suppressed, and along these lines the acceptor dissolvability is significantly improved by forming H-acceptor complexes. At that point, H atoms could be effectively separated from these deformity edifices at relatively low toughening temperatures, and in this way low resistivity p-type ZnO would be reachable with dopants from different group -V elements.

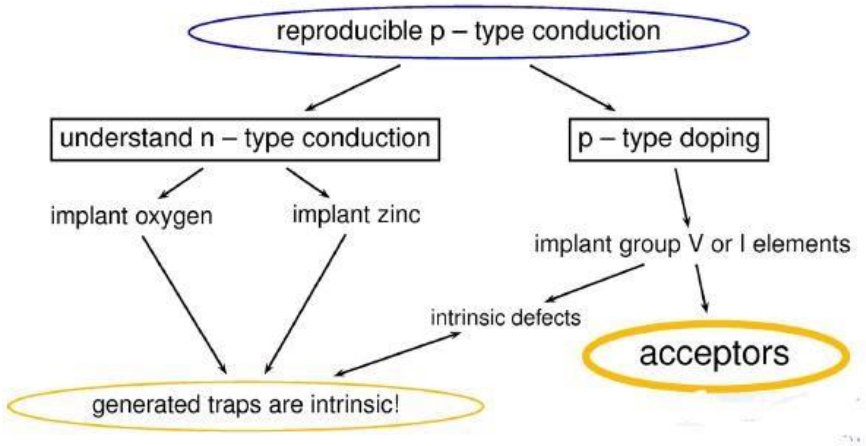

Figure 2.3: Illustration how to achieve p-type conductivity of ZnO (G Brauer, 2011).

2.1.4 Indium Zinc Oxide

Transparent conductive oxide (TCO) films such as indium tin oxide (ITO), gallium doped zinc oxide (GZO) and zinc doped indium oxide (IZO) have been studied for several applications such as solar cells, thin film transistors (TFTs) and organic light emitting diodes (OLEDs) due to their high transmittance and good electrical conductivity (G. Gonçalves, 2007). Recently, In^2O^3 (ZnO) system has become a particular focus of attention due to its good electro-optical properties associated with excellent chemical stability (Radhouane Bel-HadjTahar, 2014). Indium-doped zinc oxide (IZO) have been cultivated utilizing various techniques, sputtering, e-beam evaporation, pulsed laser deposition, chemical vapour deposition and including spray pyrolysis.

These amorphous IZO were accounted for to have the lesser compressive pressure and smoother surfaces than the polycrystalline ITO stored under a similar sputtering conditions. Wet etching characteristic of amorphous IZO films with enhanced electrical properties were additionally answered to be better than those of the polycrystalline ITO films since they could be etched effectively with weak acid concentration, for example, oxalic corrosive and formatted to the tapper shaped fine pitch design. In this way, the IZO is relied upon to be another possibility for transparent electrode particularly for meagre film transistor

(TFT)- LCDs or natural ELDs. IZO composed of indium that is well known for its high conductivity and hence can improve the conductivity of the composites, compared to Indium Tin Oxide (ITO), IZO exhibit more stability (Cristina Besleaga, 2012).

In order to increase the conductivity of ZnO, materials that have good characteristic of conductivity such as Indium can be added as dopant to Zinc Oxide. Indium zinc oxide (IZO), in particular, have been attracting significant attention because of their good conductivity, high optical transparency, and low deposition temperature (Pin Zhaoa, 2018). Indium Zinc Oxide (IZO) system has demonstrated excellent optical and electrical properties, such as high optical quality, high mobility, surface uniformity and chemical and thermal stability in various environments (J.J. Ortega, 2014).

Figure 2.4: Indium Zinc Oxide Powder.

2.1.5 Sol Gel Method

Solid material can be produced from small materials by using the process of sol-gel. Sol gel method is suitable for the making of metal oxide. The typical precursor of sol gel are Zinc Alkoxides or Zinc Chloride that undergo hydrolysis and poly-condensation reactions. Hence, the sol develops towards the arrangement of a gel-like diphasic framework containing both a liquid stage and solid stage whose morphologies extend from discrete particles to constant polymer network. Sol-gel technique is widely adopted due to its comparatively simple procedure as there is no need of costly vacuum system and it has a wide-range advantage of large area deposition and uniformity of the films thickness (Ziaul

Raza Khan, 2011). The solgel process likewise offers different points of interest including extraordinary control of the stoichiometry and simple doping in creation.

The basic and physical properties of ZnO arranged by sol-gel method utilizing different inorganic also, organic antecedents at various deposition conditions. Sol-gel is a wet chemical process based on the desirable solution and is used because of the simplicity, low cost, large area coverage, easy control of doping level, synthesis of high purity and does not require vacuum equipment. Very clear sol concentration and annealing temperature have a critical impact on the physical and electrical properties of IZO.

2.2 Application of Zinc Oxide

Unique characteristics of Zinc Oxide from chemical and physical aspects have made it widely used in many countries. It plays an important role in a very wide range of applications, ranging from tyres to ceramics, from pharmaceuticals to agriculture, and from paints to chemicals (Jesionowski, 2014). Figure 2.5 shows some applications of ZnO.

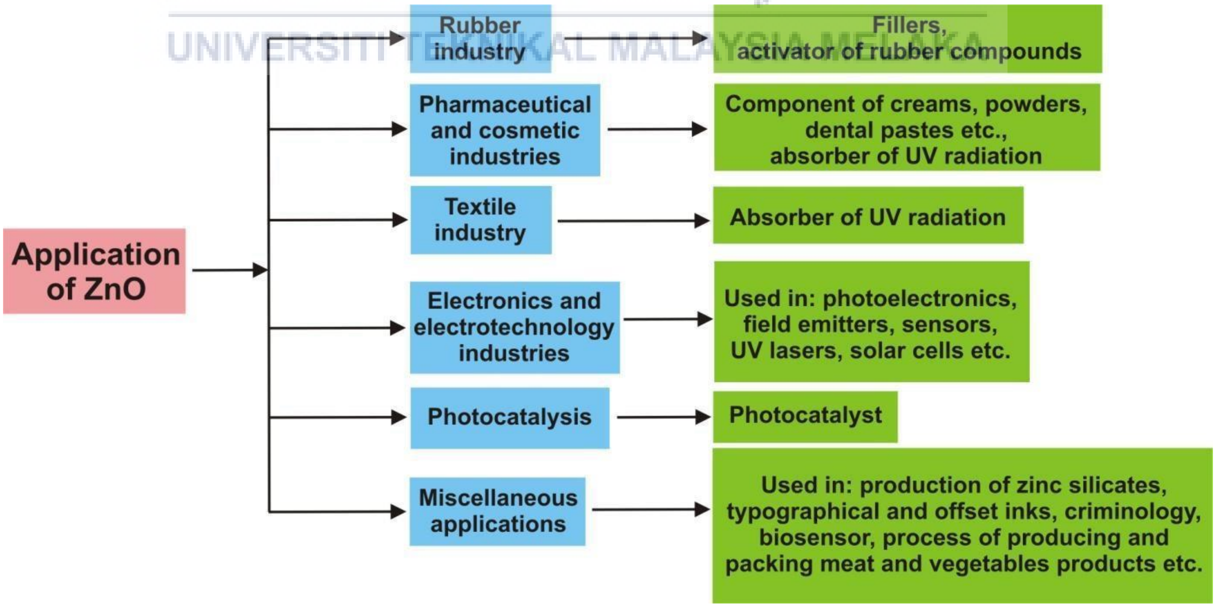

Figure 2.5: Application of ZnO (Jesionowski, 2014).

2.2.1 Rubber Industry

Low thermal conductivity of pure silicone rubber is very low, but this low conductivity can be improved by the addition of conductive filler. Conductive fillers including metal powder and metal oxide. A few sorts of thermal conductivity powder, for example, Al^2O^3, MgO, Al^2N^3, SiO^2, ZnO, are the conductive powder that have the tendency to improve the thermal conductivity of silicone rubber while holding its high electrical resistance, and are in this manner promising competitors as high performance engineering materials.

The incorporation of the particles fillers can accomplish high warm conductivity even at a moderately low filling content. Be that as it may, the ZnO particles will tend to aggregate together to produced particles of enormous size in the polymer network, because of the feeble connection between the surface of the particles and the polymer. To solve this problem, the interaction between particle and polymer surface was modified (Zhijie Yuan, 2011).

2.2.2 The Pharmaceutical and Cosmetic Industries

Because of its antibacterial, purifying and drying characteristic, zinc oxide is broadly utilized in the generation of different sorts of medicines. It was in the past utilized as an orally controlled medication for epilepsy, and later for diarrhoea. Right now it is connected locally, for the most part as balms and creams, and all the more once in a while through cleaning powders and fluid powders.

ZnO has the properties of which it can quicken wound mending, thus it is utilized in dermatological substances against irritation and itching. What's more it is utilized in dentistry, predominantly as a segment of dental glues, and furthermore for brief fillings. ZnO is likewise utilized in different sorts of nourishing items and diet supplements, where it serves to give essential dietary zinc (Mason, 2006).

2.2.3 The Textile Industry

In textiles applications, not exclusively is zinc oxide organically perfect, yet in addition particles structured ZnO coatings are more air-porous and effective as UV-blockers contrasted and their bulk counterparts (Yadav, et al., 2006). Thusly, ZnO molecule structures have turned out to be exceptionally alluring as UV-defensive material coatings. Various methods have been accounted for the generation of UV-securing materials using ZnO particle structures. For example, hydrothermally developed ZnO nanoparticles in SiO^2-covered cotton texture indicated magnificent UV-blocking properties.

synthesis of ZnO particles somewhere else through a homogeneous stage response at high temperatures pursued by their deposition on cotton and wool textures brought about noteworthy improvement in UV-retaining movement. Essentially, ZnO rod exhibits that were developed onto a fibrous substrate by a low-temperature development technique gave astounding UV protection.

2.2.4 The Electronics and Electro Technology Industries

Zinc oxide is another and significant semiconductor which possess a scope of utilizations in hardware and electrotechnology. ZnO band is wide as much as (3.37 eV) and high bond vitality (60 meV) at room temperature imply that zinc oxide can be utilized in photoelectronic (Purica, Budianu, & Rusu, 2001) and electronic equipment (Aoki, Hatannaka, & Look, 2001), in contraptions radiating a surface acoustic wave, in field makers, in sensors, in UV lasers, and in sun based cells.

ZnO likewise has the properties of luminescene. Due to this property it is utilized in Field discharge show (FED) equipment, for example, TVs. It is better than the traditional materials, sulfur and phosphorus (compoun exhibit phosphorescene), since it is increasingly impervious to UV beams, and furthermore has higher of conductivity properties of electric. The photoluminescent properties of zinc oxide rely upon the structure and size of the crystal of the compound, defect in the crystalline structure, and furthermore on temperature. ZnO is a semiconductor, and thin film made of that material presentation high conductivity and magnificent penetrability by obvious beams. These properties imply that it very well may be utilized for the generation of light-porous terminals in solar batteries.

2.2.5 Photocatalysis

Concentrated scientific search has occurred lately on photocatalysis. In this procedure, an electron-gap pair is delivered underneath the power of light by methods for oxidation or decrease responses occurring on the surface of catalyst. Within the photocatalyst presence, oxidized of organic pollutant can happen straightforwardly by methods for a photogenerated gap or indirectly by means of a response with properties of reactive groups (ROS), for instance the hydroxyl radical OH·, resulted in solution.

The common used catalyst are TiO^2 and ZnO. TiO^2 shows photocatalytic action beneath the intensity UV light. ZnO gives comparable or better action than that of TiO^2, however is not very stable and lack of sensitive to photocorrosion (Hariharan, 2006). Better stability, in any case, is given by zinc oxide of nanometric measurements, which offers better crystallinity and littler imperfections. The photocatalytic activity of ZnO can be additionally improved, and the scope of the obvious range for zinc oxide can be stretched out, by including other compound.

2.2.6 Miscellaneous Applications

Aside from above application that have been mentioned, zinc oxide can likewise be utilized in different parts of industry, including for instance solid creation. The expansion of zinc oxide improves the procedure time and the opposition of cement to the activity of water. Zinc oxide responds with silicates to create zinc silicates, which are water proof and fire proof materials utilized as covers in paints. These fire proof and adhesive substances are utilized in the authoritative of concretes utilized in the construction industry.

ZnO is likewise utilized for the creation of typographical and offset inks. It gives great printing properties. The expansion of ZnO implies that the inks have better covering power, unadulterated shade and high strength, and averts obscuring. Zinc oxide is likewise utilized in colours to create shine. It is added to numerous nourishment items, including breakfast cereal. ZnO is utilized as a source of zinc, which is a fundamental supplement. Due to their extraordinary substance and antifungal properties, zinc oxide and its subordinates are also used amid the process producing and pressing of the meat product as well as the vegetable products (Espitia, et al., 2012). ZnO and its subordinates smother the improvement and development of fungi and molds. Zinc oxide is added to fungicides to improve their viability. Zinc oxide is additionally being utilized progressively frequently as animal feed added substance, as it underpins the right development of animal. It is additionally utilized as artificial fertilizer.

Zinc oxide additionally has utilized in criminology, in mechanical unique mark analysis. It is likewise a fixing in cigarette channels, as it specifically expels certain segments from tobacco smoke. Channels are made of charcoal impregnated with ZnO and Fe^2O^3, which evacuate huge amounts of HCN and H^2S from tobacco smoke without delivering a smell. It additionally expels sulfur and its mixes from different fluids and gases, especially mechanical waste gases. Zinc additionally expels H^2S from hydrocarbon gas, and desulfurizes H^2S and other sulfur parts. ZnO and its subsidiaries are additionally utilized as an added substance to vehicle greasing up oils, decreasing utilization and oxygen consumption. Zinc oxide has additionally been utilized in different sorts of ointments, for example, those with EP added substances, vibration resistant greases and solid lubricant. Later on, advantages may likewise be taken of the cement properties of ZnO.

2.3 Electromagnetic Interference (EMI)

The development in the use of electronic gadgets over a wide range of military, mechanical, business and shopper segments has made another type of contamination. This contamination or pollution is called as electromagnetic interference (EMI) or also known as radio frequency interference (RFI). Electromagnetic interference (EMI) is described as the unwanted noise created by electromagnetic (EM) waves (M. Satish Kumar, 2018). The effects of EMI can cause malfunctions of electronic devices such as laptops, mobile phones and wireless headphones. EMI also can be harmful to the human body, EMI has a significant influence on the performance of electronic devices, and it may even affect the human body by causing vertigo, nausea, or muscle stimulation (Duck Weon Lee, 2019). Bandwidth is one of the EMI types, there are two types of bandwidth such as narrowband EMI and broadband EMI. Narrowband EMI regularly radiates from proposed transmissions, for example, radio and TV stations or cell phones while broadband EMI is inadvertent radiation from sources, for example, electric power transmission lines.

Due to this reasons, EMI shielding is needed to blocked the EMI or reduce the effects of EMI so that all the problems faced can be avoided or minimize. Generally shielding materials are made primarily from metals, which are known to have great mechanical and electrical properties but metals have some major disadvantages that needed to be replaced by new materials. Some of their disadvantages are high cost of materials, susceptible to corrosion and high density. Due to this reasons, many researches have been carried out to find the suitable materials that comparable to the metals so that it can substitute the use of metals in EMI shielding.

EMI shielding is the way to block the EMI effects by using barrier made form conductive or magnetic materials. Metals are commonly used as shielding materials but because of the density and corrosion issues so there is an urgent need for advanced shielding materials that are light in weight, flexible, chemically and thermally stable and most importantly be thermally conductive (Anisha Chaudharya, 2019). Natural fibres has been broadly considered as one of the materials that can be profit by the expense and mechanical properties as replacing the metals. Natural fibres have the potential of replacing the metals as it has lighter weight and low processing cost compared to metals.

To make the composite to be able to have the characteristic of conductivity so that it can acts as EMI shielding, IZO filler is added. IZO composed of indium that is well known for its high conductivity and hence can improve the conductivity of the composites, compared to Indium Tin Oxide (ITO), IZO exhibit more stability (Cristina Besleaga, 2012).

2.4 Summary

Literature review is the part where related project and researches are been carried out previously. By completing the chapter 2, more information and knowledge are obtained from various journals that can assist in finishing this project. From this literature review also the most appropriate parameters and method can be classified and used in this project as it is having been proven by the researchers.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Chapter 3 will be discussed about the methodology of the study that consist of analysis and implementation of method used to complete the project. In this chapter, selection of material, laboratory testing and also research design will be showed. Previous researches has studied the characteristics and specifications related to the project, using the previous research as reference, the most appropriate method and techniques obtained from the previous research will be apply in this chapter in order to complete this project. The use of methodology in research is so that the research or study can be carried out in a very smooths and systematic ways to achieve the objectives and within the scopes of study. Figure 3.1 shows the flowchart of this study.

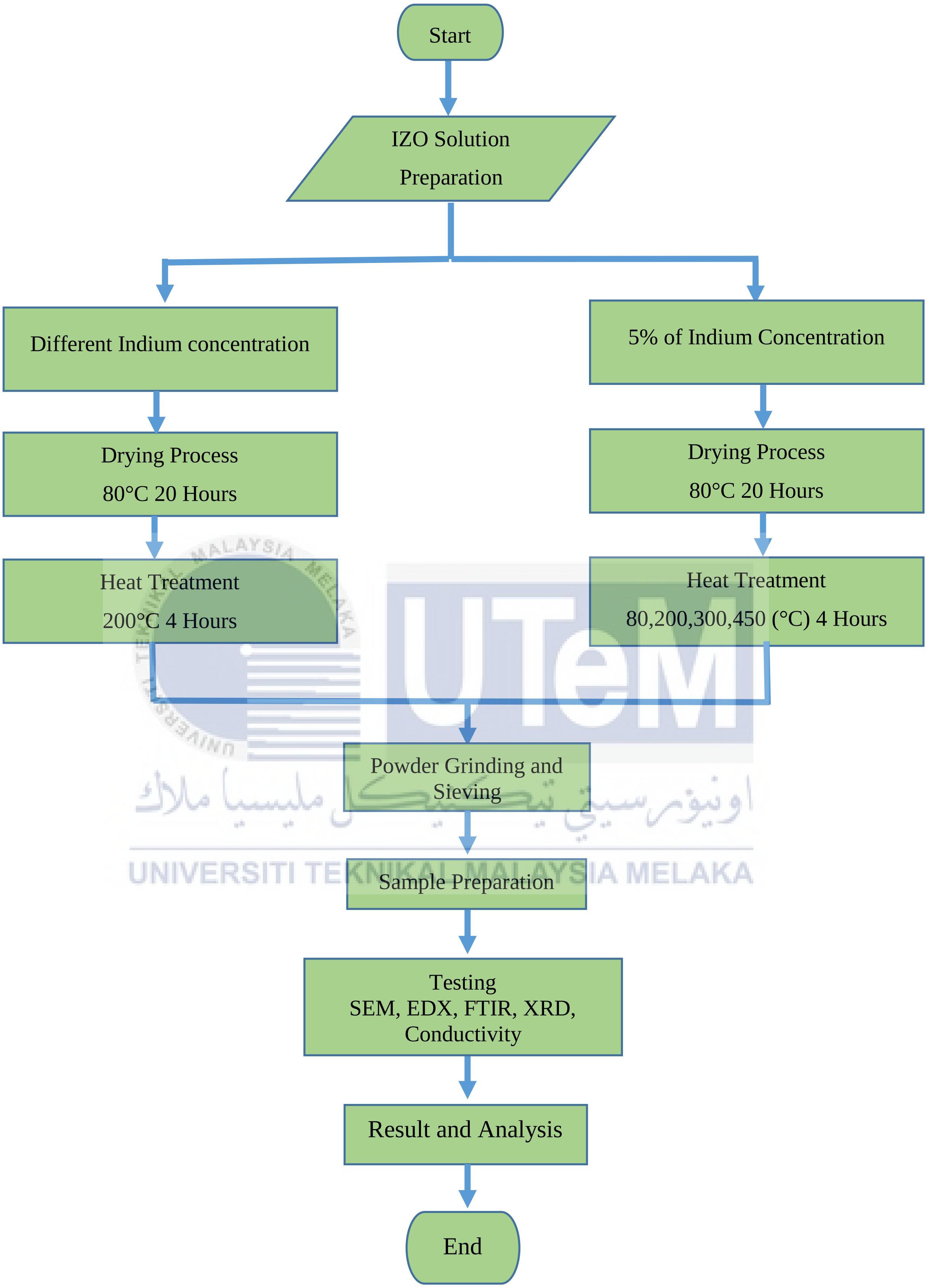

Figure 3.1: Flowchart of Process

3.2 Methodology

This project consists of 4 main parts that can be described as part 1which was the solution preparation, then part 2 was about the making of powder based on the parameter set for the testing for example different percentages concentration of indium doping and different annealing temperature of same indium concentration, furthermore the part 3 was where the sample preparation took place for the testing. There are five types of testing that have been conducted which are Scanning Electron Microscopy (SEM), Energy Dispersive X-Ray (EDX), Fourier Transform Infrared Spectroscopy (FTIR), X-Ray Diffraction (XRD) and Electrical conductivity test. Lastly was part 4, part where the results of testing were observed and studied for discussion and analysis.

3.3 IZO Solution Preparation

The very first step in methodology in this project was solution preparation. The solution was obtained by dissolving 0.1M of zinc acetate dihydrate in 500ml of absolute ethanol in beaker. The weight of zinc acetate dihydrate for 500ml of absolute ethanol was calculated by the Equation 1. The solution then was stirred for 2 hours at 300rpm and the temperature was asset at 25°C. After 1 hour when the solution became clear, the Indium was added to the solution according to the concentration parameter such as 3%, 5% and 7% of Zinc Oxide weight percentages. The calculation was performed to calculate the weight of indium percentages by the Equation 2. The solution then was continued to stir for 2 hours and the temperature was asset at 75°C at 300rpm. After the solution was well dissolve and became clear after stirred for 2 hours, it was then stored for 24 hours at room temperature.

Mass (g) = concentration(mol/L) ×Volume(L)×Molecular weight (g/mol) Equation 1

Mass (g) = mass (g) Zinc Acetate Dihydrate × Percentage of Indium (%) Equation 2

Figure 3.2: Magnetic Stirrer

3.3 Drying Process

Drying might be characterized as the vaporization and evacuation of water or different fluids from a solution, suspension, or other solid liquid mixture to shape a dry solid. It is a confounded procedure that includes synchronous warmth and mass exchange, joined by physicochemical changes. Drying happens because of the vaporization of solution by providing heat arrangement. In drying process, the heat transfer and the mass transfer are very critical aspects. Heat was transferred to the product to dissipate liquid, while mass transferred as vapour to the surrounding gas.

After Indium Zinc Oxide solution was kept for 24 hours at room temperature the process of drying the solution took place. The solution was poured into cleaned petri dish before it was put inside the drying oven. Then, the temperature for the oven was set at 80°C while the time for the solution to dry was set up at 20 hours. When the drying process was done, the petri dishes were taken out from the drying oven and the dried solution that have become solid was scraped from the petri dishes.

Figure 3.3: Dried solid of IZO

Figure 3.4: Memmert Drying Oven

3.4 Heat Treatment

3.4.1 Heat Treatment of Different Indium Percentages Concentration

Powder metal (PM) component can be produced from several processes and operations, one of the most common and crucial process of making powder metal is by using heat treatment. This heat treatment process is necessary in powder metallurgy part as it is one of the way that can improve the properties of the final part of the powder such as the improvement properties of strength and hardness. With drying process alone, some of these properties can be obtained, but there are more desired properties that can only be achieved by using the heat treatment process.

Heat treatment of different doping concentration was performed to see the effect of indium doping concentration on the electrical properties of Indium Zinc Oxide. Four samples of different indium percentages concentration of Indium Zinc Oxide were put inside four different small ceramic crucibles. The concentration of the indium used were 0%, 3%, 5% and 7%. The ceramic crucibles were later put inside a furnace for heat treatment process. The temperature of the heat treatment was set up at 200°C for 4 hours. To set the rate of temperature increase every 10 minutes to achieve the temperature of 200°C a calculation was performed by using Equation 3. The cooling process of 200°C furnace took at least half a day because it was cooling using standard normal room temperature without any other process or method of cooling applied to the furnace.

Rate of temperature increase = [200°C - current temperature of furnace (°C)]/10 Equation 3

Figure 3.5: Ceramic Crucible

3.4.2 Heat Treatment of Different Annealing Temperature

Heat treatment of different annealing temperature experiment was carried out to study the effect of different annealing temperature on the microstructure and electrical properties of Indium Zinc Oxide. Three samples of different annealing temperature were applied to the 5% indium concentration of Indium Zinc Oxide. By using crucible, the dried Indium Zinc Oxide solid of 5% Indium concentration were placed inside the furnace. The annealing temperature set up for this process are 200°C, 300°C and 450°C.The same Equation 3 was used to find the rate of increasing temperature of furnace to set up the annealing temperatures. The duration of the time taken for the heat treatment process for annealing temperature was still the same as 4 hours. The time taken for the furnace of annealing temperature to cool down took a longer time than the time taken for the furnace of different Indium concentration. This was because of the higher temperature of the annealing needed more time to cool down as the only cooling method was using the standard room temperature.

Figure 3.6: Ceramic Furnace

3.5 Powder Grinding and Sieving

After heat treatment was done, the powder obtained from the heat treatment process was grind and sieved. The powder was grind using ball mill. Ball milling process is where a powder mixture put in the ball mill and exposed to high-vitality impact from the balls. Other than materials synthesis, high-vitality ball milling is a method for altering the conditions where synthetic responses as a rule occur either by changing the reactivity of as-processed solids or by initiating compound responses amid milling (mechanochemistry). It is, besides, a method for actuating stage changes in beginning powders whose particles have all a similar substance composition. The ball mill framework comprises of one turn circle (turn table) and two or four bowl. The turn disc pivots in a single direction while the bowl turn the other way. The centrifugal forces, made by the pivot of the bowl around its very own axis together with the revolution of the turn disc, are connected to the powder blend and milling balls in the bowl. The powder mixture is cracked and cold welded under high energy impact. In time when the high energy ball milling process, the particles of the powders were exhibit to the high energetic impact.

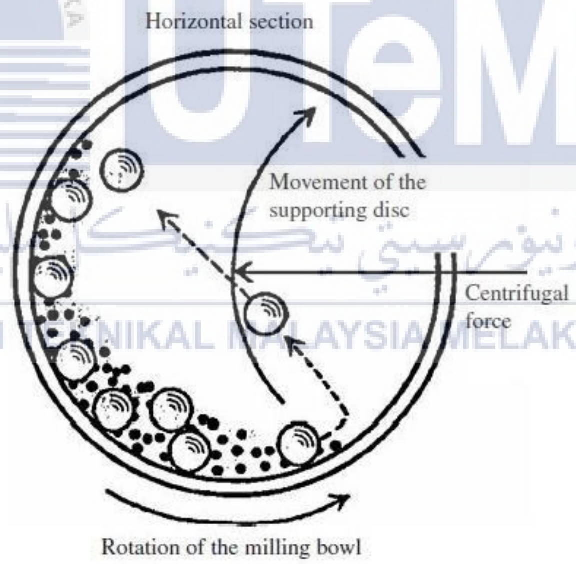

Figure 3.7: Illustration of motion of the ball and powder

Sieve analysis is a way for deciding the molecule size estimation appropriation of a material. The procedure isolates fine particles from all the more course particles by going the material through various sifters of various work sizes. This permits the mass division of particles inside each size range to be estimated and an aggregate mass dispersion built. Sieve analysis is the most established and most generally realized technique used to describe molecule measure appropriations and is utilized all through various industries.

The powder of Indium Zinc Oxide was placed inside an electric sieve shaker. In order to get into a fine powder with size similar same size, the size of the sieve used in producing the fine powder was 75 micro meter. Indium Zinc Oxide powder was sieved by using the size of 75 micro meter. For every successful powder that managed to pass through the size of 75 micro meter it was taken as for further step as a sample preparation for. The siever was cleaned every time the different parameter of powder needed to be use.

Figure 3.8: Electric Sieve Shaker

3.6 Sample Preparation

Samples preparation is a way that samples treated to its prior analyses. Sample preparation is a significant advance in most expository strategies, on the grounds that the procedures are regularly not receptive to the analyte in its structure, or the outcomes are contorted by meddling species.

For samples preparation for this project, all the fine powder obtained after sieving was used as the samples testing. Samples preparation for different Indium concentration were prepared by weighing 0.3-gram of 0%, 3%, 5% and 7% of Indium concentration using electronic weighing scale. The samples for different annealing temperature also were prepared with the same procedure with 0.3-gram Indium concentration of 80°C, 200°C, 300°C and 450°C. These samples in the form of powder were send to four different types of testing. They were Scanning Electron Microscopy (SEM), Energy Dispersive X-Ray (EDX), Fourier Transform Infrared Spectroscopy (FTIR) and X-Ray Diffraction (XRD).

Figure 3.9: Electronic Weighing Scale

Another test that was carried out was conductivity test. For conductivity test, the samples were prepared by weighing the powder to 0.3 gram of each parameters. The powders then were placed in a pellet mold. The powders in the mold was then pressed using manual hydraulic press for three minutes at the pressure of 5 tonne. After three minutes, remove the pellet inside the mold. The pellet measurement obtained from the hydraulic press was 10mm diameter × 2.15mm thickness.

Figure 3.10: Hydraulic Press

3.7 Testing

There are five types of testing that were performed on this project. There are Scanning Electron Microscopy (SEM), Energy Dispersive X-Ray (EDX), Fourier Transform Infrared Spectroscopy (FTIR), X-Ray Diffraction (XRD) and Electrical conductivity test.

3.7.1 Scanning Electron Microscopy (SEM)

The scanning electron microscopy (SEM) is a standout amongst the most adaptable instruments accessible for the examination and investigation of the microstructure morphology and substance creation portrayals. It is important to know the fundamental standards of light optics so as to comprehend the basics of electron microscopy. Images arrangement in the SEM is subject to the securing of sign delivered from the electron pillar and example communications.

Figure 3.11: Scanning Electron Microscopy

3.7.2 Energy Dispersive X-Ray (EDX)

The Energy Dispersive X-Ray (EDX) microanalysis is associated with various biomedical fields of concentrate because of its high affectability in identifying the various components in tissues. Actually, EDX method is made especially valuable in the investigation of medications conveyance in which the EDX is a significant instrument so as to distinguish nanoparticles (for the most part, used to improve the helpful execution of some chemotherapeutic operators). EDX is additionally utilized in the investigation of natural contamination and in the portrayal of mineral bioaccumulated in the tissues. All in all, the EDX can be considered as a valuable instrument in all works that require component assurance, endogenous or exogenous, in the tissue, cell or some other example.

3.7.3 X-Ray Diffraction (XRD)

X-ray powder diffraction (XRD) is a fast expository system essentially utilized for stage recognizable proof of a crystalline material and can give data on unit cell measurements. The dissected material is finely ground, homogenized, and normal mass organization is resolved. X-ray diffractometers comprise of three essential elements, an X-ray tube, an example holder, and an X-ray identifier. X-ray created in a cathode ray tube by warming a fibre to deliver electrons, quickening the electrons toward an objective by applying a voltage, and barraging the objective material with electrons. At the point when electrons have adequate vitality to remove inward shell electrons of the objective material, trademark X-ray spectra are created.

Figure 3.12: XRD Machine

3.7.4 Fourier Transform Infrared Spectroscopy (FTIR)

FT-IR stands for Fourier Transform InfraRed, the favored technique for infrared spectroscopy. In infrared spectroscopy, IR radiation is gone through an example. A portion of the infrared radiation is consumed by the example and some of it is gone through (transmitted).

The subsequent range speaks to the sub-atomic ingestion and transmission, making a subatomic unique mark of the example. Like a fingerprint, no two one of a kind atomic structures produce a similar infrared range. This makes infrared spectroscopy valuable for a few kinds of analysis. Infrared spectroscopy has been a workhorse strategy for materials investigation in the research center for more than seventy years. An infrared range speaks to a unique mark of an example with assimilation crests which compare to the frequencies of vibrations between the obligations of the molecules making up the material. Since each extraordinary material is an exceptional blend of molecules, no two mixes produce precisely the same infrared range.

Figure 3.13: FTIR Spectroscopy

3.7.5 Electrical Conductivity Test (4 Point-Probe)

Electrical conductivity test was carried out to study the effects electrical properties of Indium doping concentration on different percentages of Indium Zinc Oxide and also on the effect on the annealing temperature of Indium Zinc Oxide.

The conductivity test was carried out by using 4 point-probe machine. A 4 point-probe is a simple machine to estimate the resistivity of semiconductor samples. By going a current through two external probes and measuring the voltage through the inward probe permits the estimation of the substrate resistivity.

Figure 3.14: 4 Point-Probe

CHAPTER 4
RESULT AND DISCUSSION

This chapter presents the results and discussion of the project. Some of the result and finding are supported by the previous researches with further justification and consideration through the observation and comparison.

4.1 Overview

The main objectives of the project are to study the effect of Indium concentration and the microstructure of the Indium Zinc Oxide due to the different percentages of Indium and annealing temperature. The result and findings in this project were obtained via various characterization methods such as SEM, EDX, XRD, FTIR and conductivity test.

4.2 Scanning Electron Microscopy (SEM) Analysis

The microstructure and shape of Indium Zinc Oxide particle were analysed by the SEM. Figure 4.1 (a) to 4.1 (d) shows the microstructure of IZO particles of different concentration of Indium doping percentages with the same temperature of 200°C. Based on the SEM images, it is obvious that the shape of the IZO particles were not spherical. This is due to the size particles of the IZO powder were not in nanoparticles and was only sieved using 75 micro meter siever.

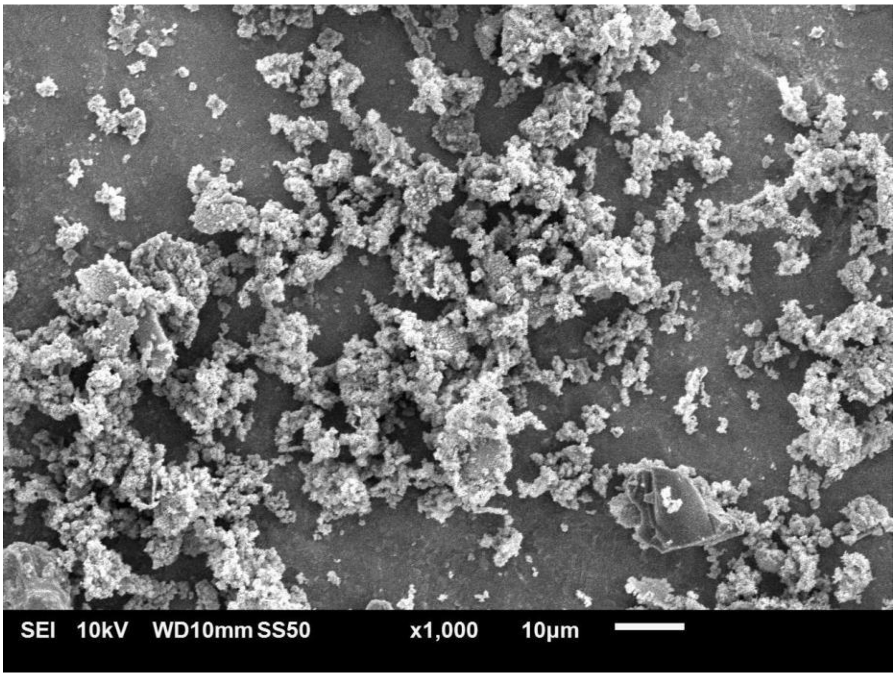

Figure 4.1(a): 0% Indium

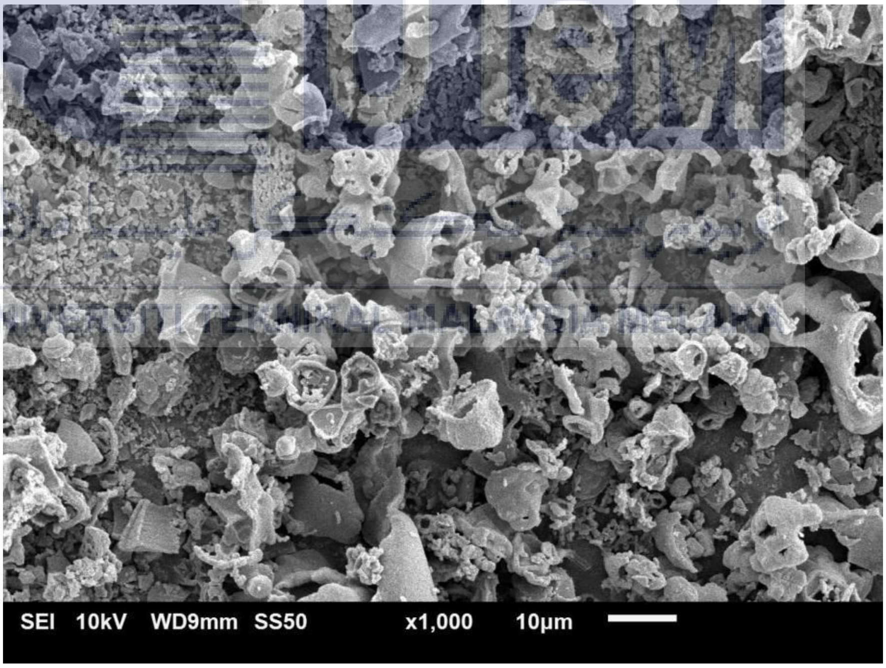

Figure 4.1(b): 3% Indium

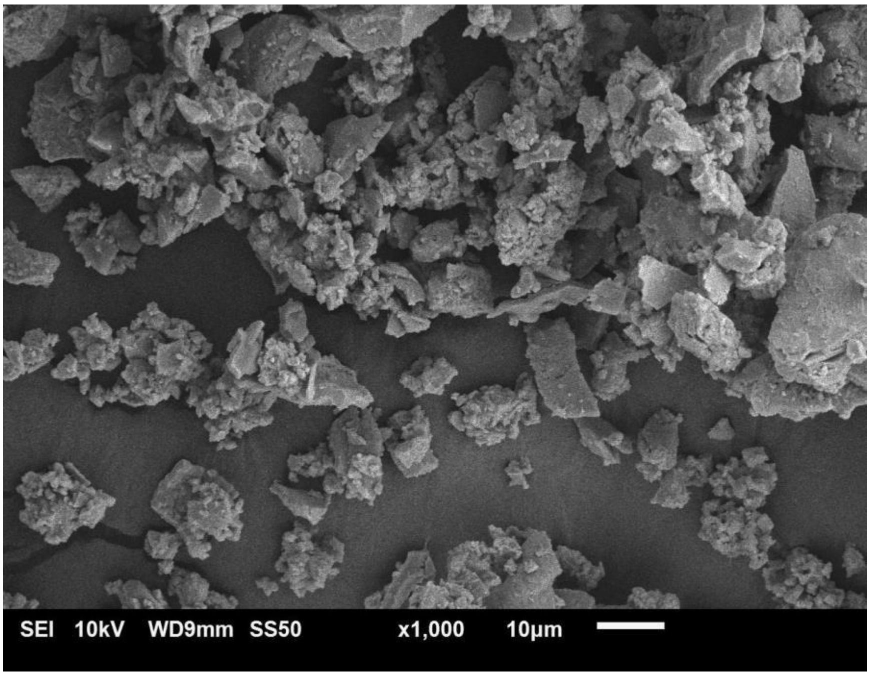

Figure 4.1(c): 5% Indium

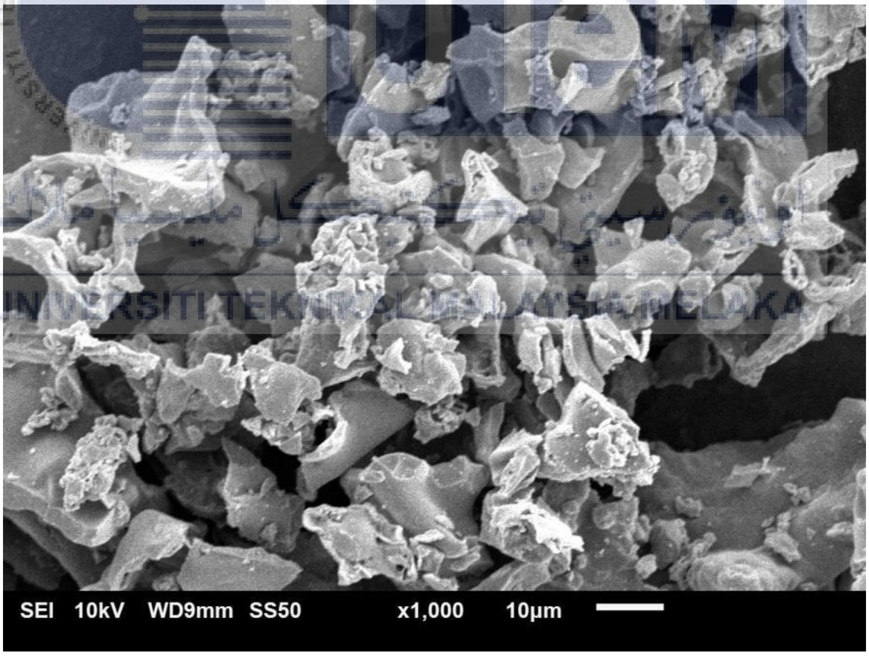

Figure 4.1(d): 7% Indium

SEM also was performed for IZO particles a different annealing temperature with same concentration percentages of 5% Indium. From figure 4.2(a) to 4.2(d), the images captured by the SEM were shown. From the SEM images, it is clear to see that the microstructure of IZO particles changes as the temperature increase. From the SEM images also it can be seen that the particles size of the IZO particles were became smaller when higher temperature was applied.

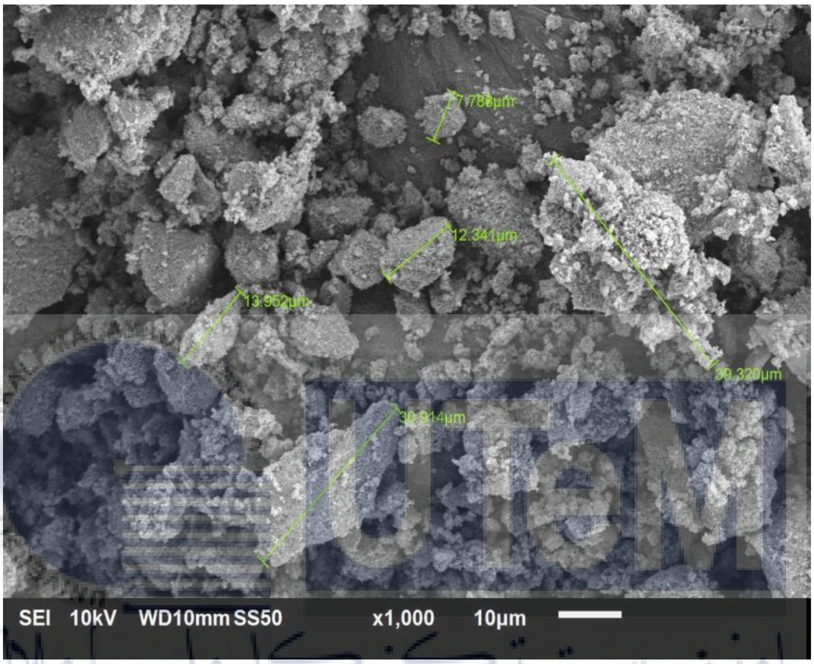

Figure 4.2(a): 5% Indium 80°C

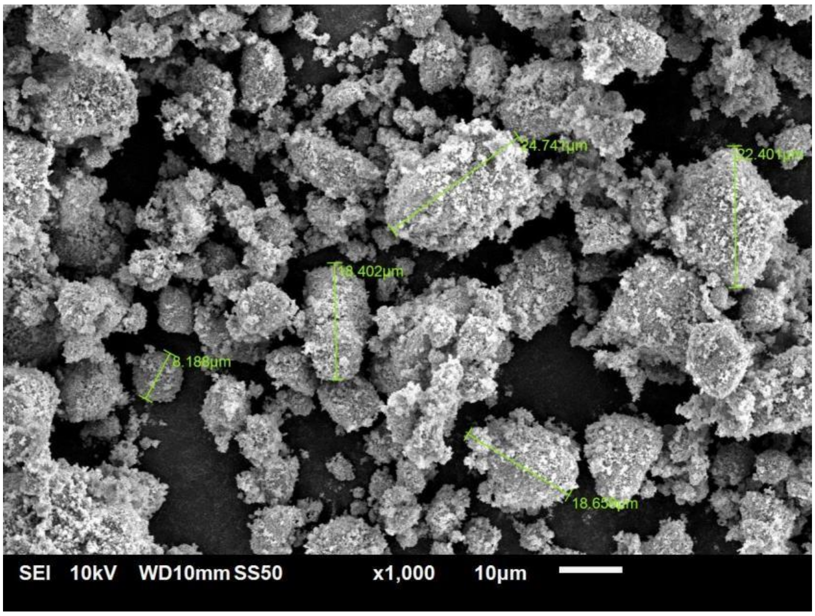

Figure 4.2(b):5% Indium 200°C

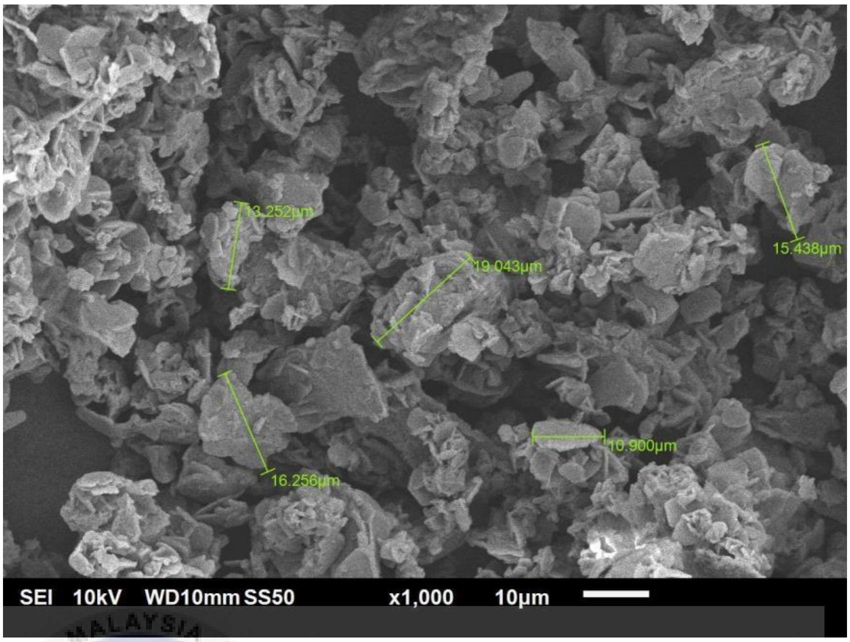

Figure 4.2(c): 5% Indium 300°C

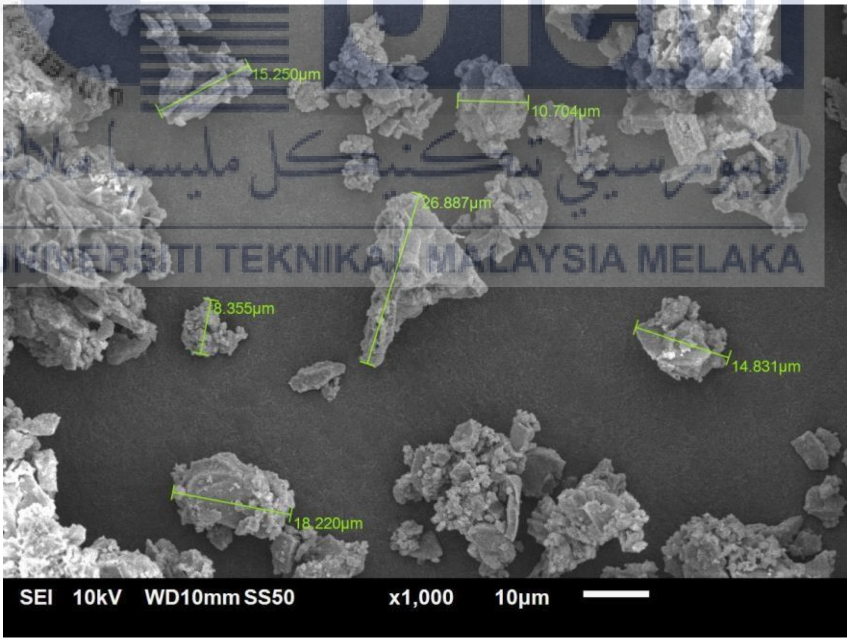

Figure 4.2(d): 5% Indium 450°C

4.3 Electron Dispersive X-Ray (EDX)

The Energy Dispersive X-ray Diffractive (EDX) was performed for the analysis IZO particles to know about the elemental composition. EDX affirms the presence of various components including Zinc, Oxygen and Indium in the Indium Zinc Oxide particle. This analysis also demonstrated the peak that related to the optical absorption of the produced particle. Different concentrations of Indium doping were tested to justify the presence of the IZO components. Figure 4.3(a) to 4.3(c) shows the presence of components in the IZO particles. The tables 4.3(a) to 4.3(c) shows the composition of the IZO particles.

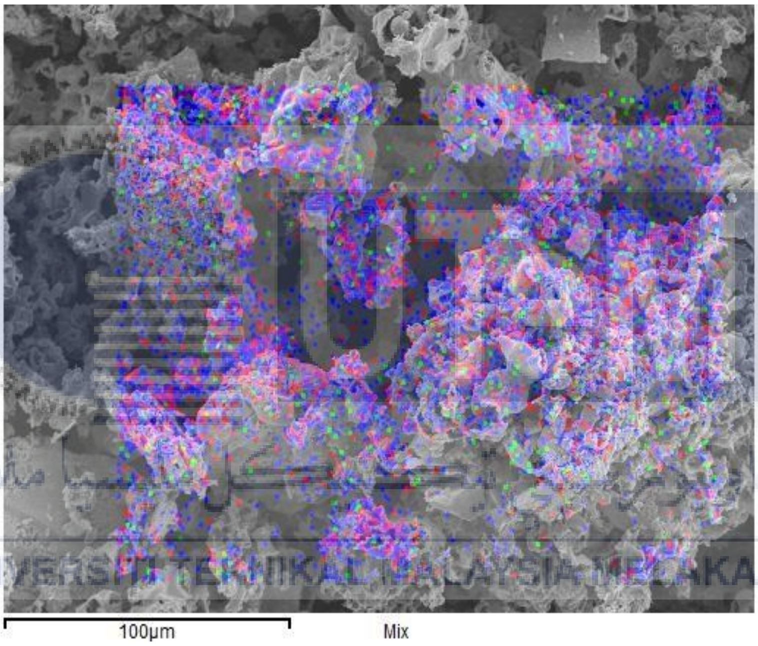

Figure 4.3(a): 3% Indium 200°C

Table 4.3(a): Composition 3% Indium Zinc Oxide

Spectrum	In stats.	O	Zn	In	Total
Sum Spectrum	Yes	23.25	72.59	4.16	100.00
Mean		23.25	72.59	4.16	100.00
Std. deviation		0.00	0.00	0.00	
Max.		23.25	72.59	4.16	
Min.		23.25	72.59	4.16	

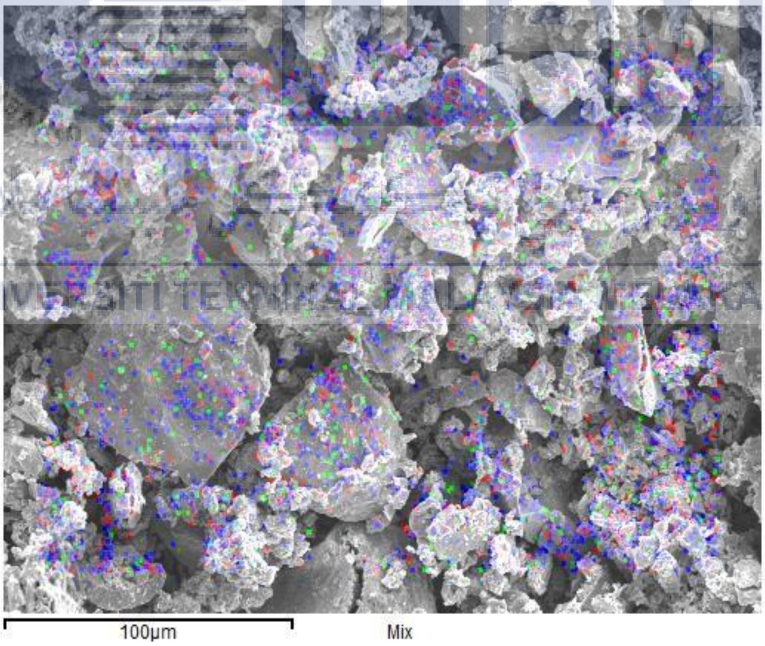

Figure 4.3(b): 5% Indium 200°C

Table 4.3(b): composition 5% Indium 200°C

Spectrum	In stats.	O	Zn	In	Total
Sum Spectrum	Yes	29.05	64.37	6.57	100.00
Mean		29.05	64.37	6.57	100.00
Std. deviation		0.00	0.00	0.00	
Max.		29.05	64.37	6.57	
Min.		29.05	64.37	6.57	

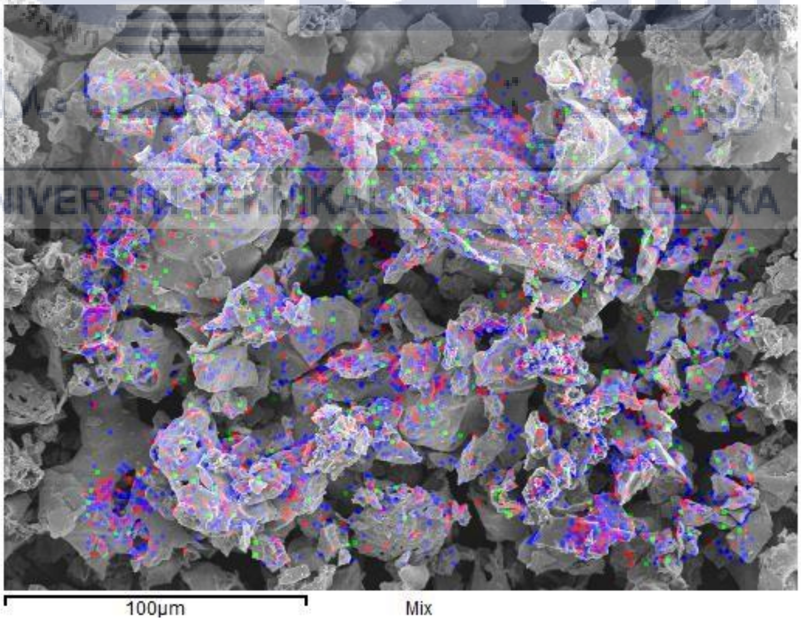

Figure 4.3(c): 7% Indium 200°C

Table 4.3(c): composition 7% Indium 200°C

Spectrum	In stats.	O	Zn	In	Total
Sum Spectrum	Yes	27.32	68.26	4.42	100.00
Mean		27.32	68.26	4.42	100.00
Std. deviation		0.00	0.00	0.00	
Max.		27.32	68.26	4.42	
Min.		27.32	68.26	4.42	

4.4 X-Ray Diffraction (XRD)

Phase analysis of Indium Zinc Oxide was studied under the test of XRD. Figure 4.4(a) shows the XRD pattern of pure ZnO and different concentration of percentages of IZO. From the XRD patterns, it clearly can be seen that there are strong diffraction peak ranged between 30° to 40° (M. Hossein Manzari Tavakoli, 2018). From the graph, the intensity of the ZnO is the highest but after the addition of Indium, the peak of the XRD pattern changed. The intensity of the IZO particles peak were decreased as more Indium percentage was added.

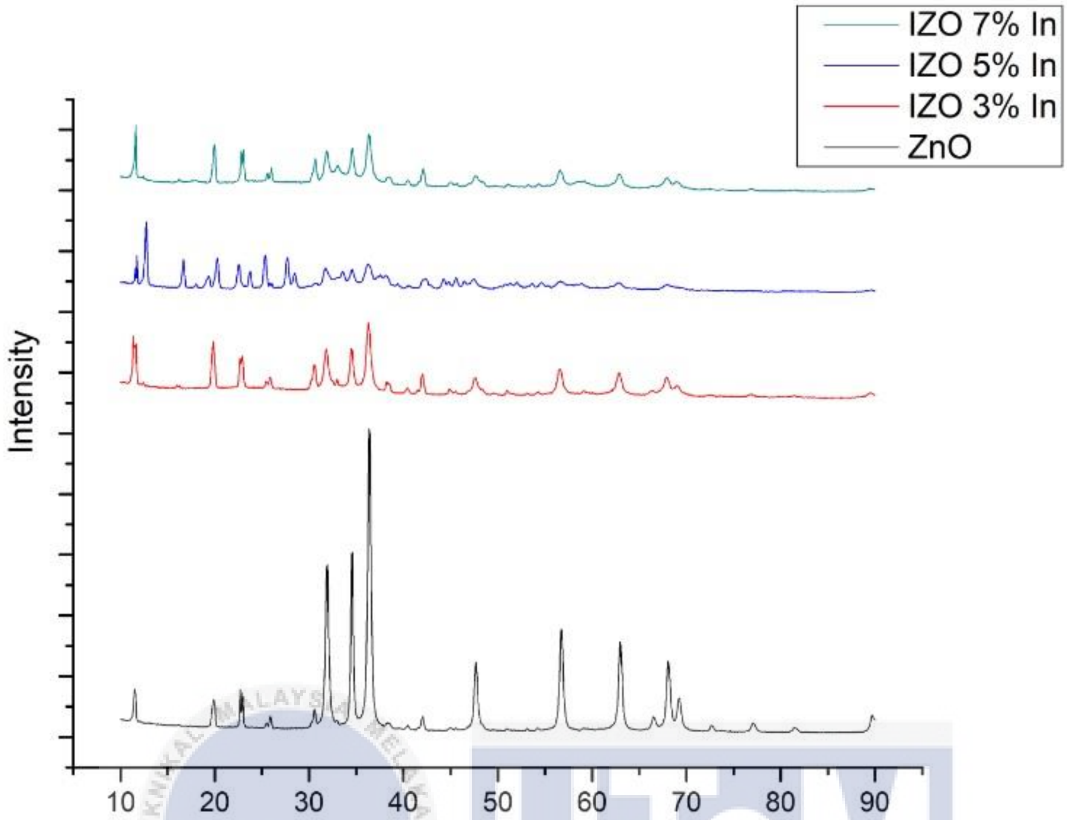

Figure 4.4(a): XRD pattern of undoped ZnO and doped ZnO

As for XRD pattern on different annealing temperature of doped Indium ZnO, it can be observed that there are significant changes in the XRD graph. Figure 4.4(b) shows the XRD pattern of the different annealing temperature. From the pattern, the peak and intensity of doped Indium Zinc Oxide changed and shifted to the right as the temperature of annealing applied were getting higher. This changed indicate that there was improvement in the crystalline structure of IZO particles after higher heat temperature was applied to the IZO particles.

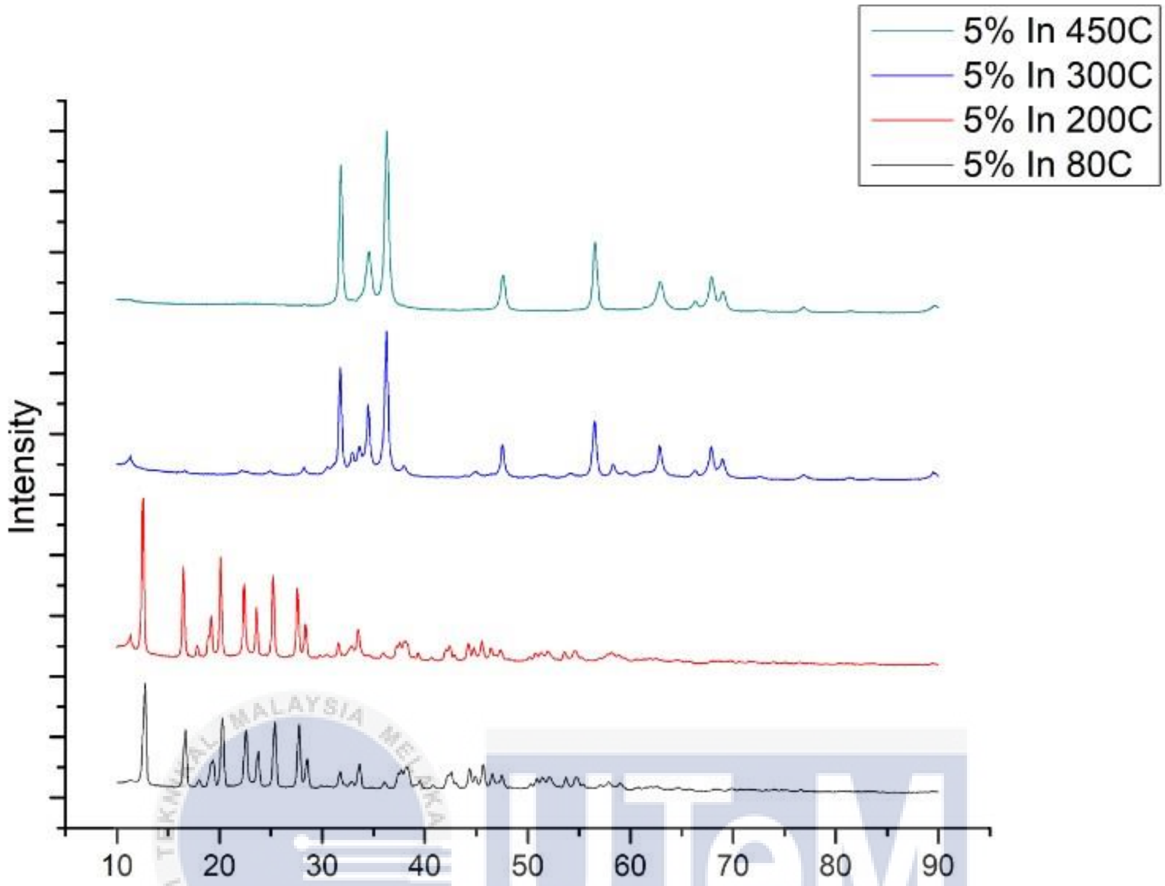

Figure 4.4(b): XRD pattern of different annealing temperature

4.5 Fourier Transform Infrared Spectroscopy (FTIR)

FTIR studies were completed to determine the purity and nature of the particles. Figure 4.5(a) shows the FTIR of different concentration of Indium doping concentration on IZO particles. This analysis showed the peak and the corresponded of the produced IZO particles. The peak at 533 shows the characteristic absorption of Zn-O bond (Snehal Yedurkar, 2016). As shown in figure, the peak ranged from 1500 to 1700 indicate the particles exhibit the characteristic of COO^-. The peak ranged from 2900 to 3600 indicate that there is the presence of hydroxyl group (Amit Kumar, 2014).

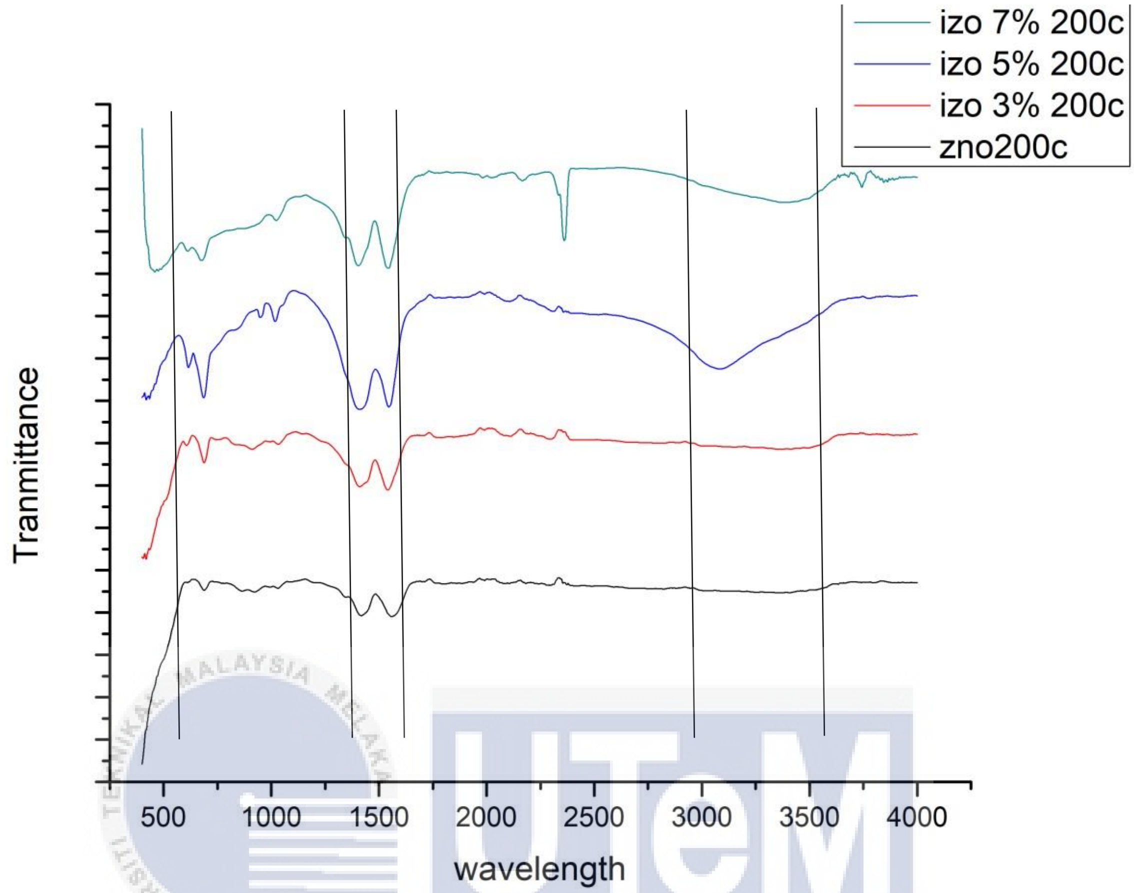

Figure 4.5(a): FTIR of different concentration of Indium doping

Figure 4.5(b) shows the FTIR graph of different annealing temperature of IZO. This analysis showed the peak and corresponded of the produced IZO at different annealing temperature of the same indium concentration doping. From the graph, it can be observed that, at ranged of 533 the absorption of ZnO or the of hexagonal phase of ZnO. At the range of 1400 to 1600 as the temperature increased the intensity of the IZO became smaller this result as the removal of the COO^-. From the peak of 2800 to 3200 the peak became smaller because the hydroxyl group was removed by the effect of temperature applied to the IZO particles.

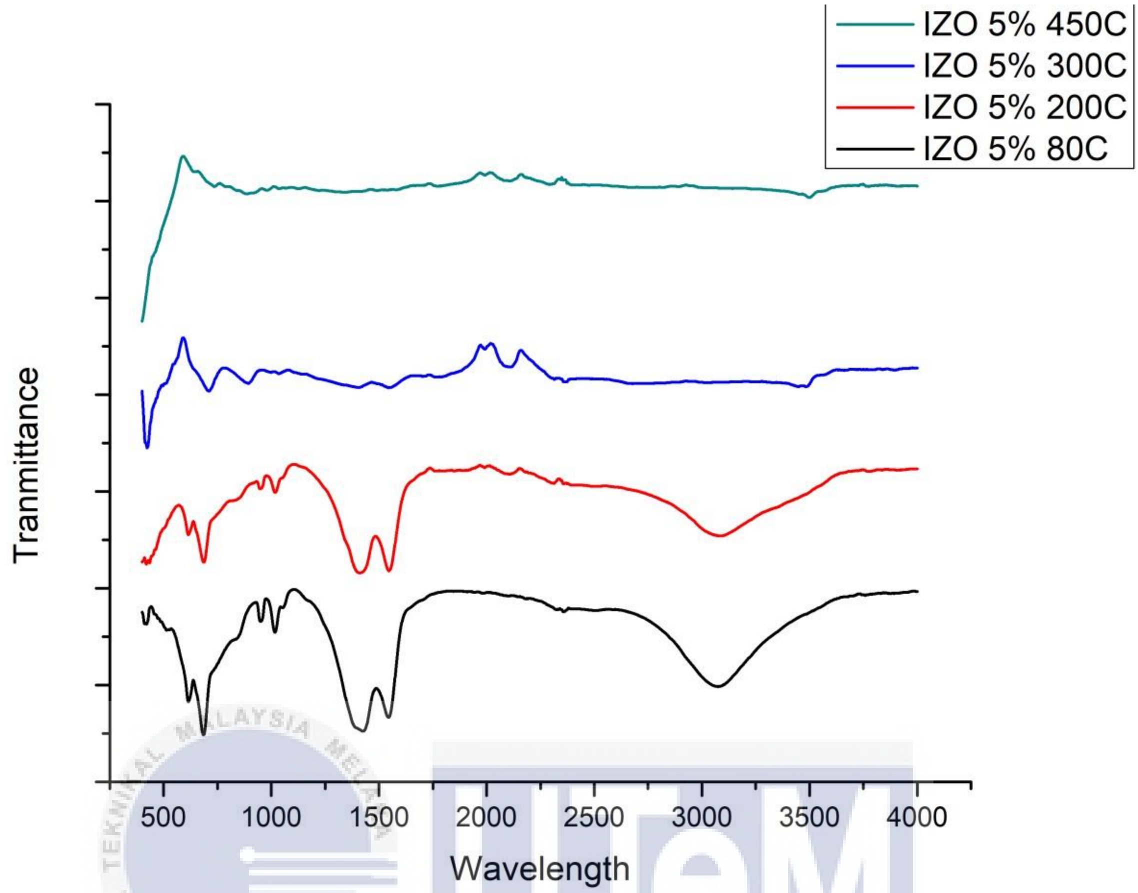

Figure 4.5(b): FTIR of different annealing temperature of IZO

4.6 Analysis of Conductivity Test

Conductivity test was conducted to observe the effect of concentration of indium doping and the effect on the conductivity of the IZO particles by increasing the temperature of heat treatment applied to the IZO powder. The conductivity test was conducted by using 4 PointProbe. Results obtained from the conductivity test were recorded in tables. Table 4.6(a) showed the result of conductivity test from different Indium concentration doping on IZO particles. From the table, the conductivity of the IZO particles increased as the percentages of Indium added was increased. The highest conductivity recorded for the different concentration of Indium was at 7%.

Table 4.6(a): Effect of Indium Concentration on Indium Doping

	Temperature °C	Indium percentage (%)	Conductivity (S/cm)
ZnO	200	0	1.78E-8
IZO	200	3	1.9E-8
IZO	200	5	4.73E-8
IZO	200	7	3.36E-7

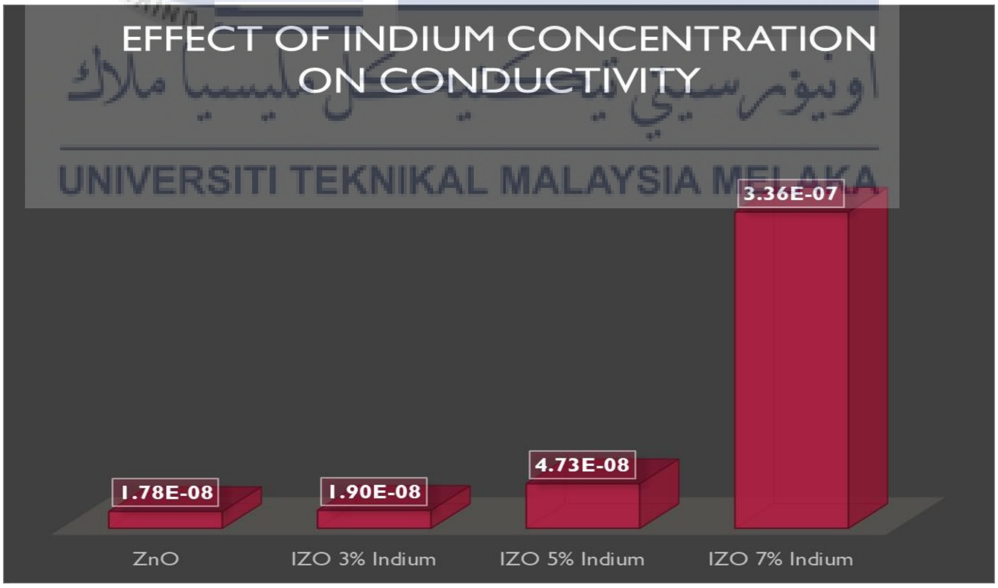

Figure 4.6(a): Bar Chart of Indium Concentration on conductivity

Another conductivity test that was carried out was on the effect of different annealing temperatures applied to the 5% of Indium doping concentration. Table 4.6(b) shows the result obtained for this conductivity test. From the table, it was obvious that when the annealing temperatures were applied the conductivity of IZO particles increased. For the highest conductivity obtained from this test, it was at the temperature of 450°C.

Table 4.6(b): Effect of annealing temperature on conductivity

	Temperature °C	Indium percentage (%)	Conductivity (S/cm)
IZO	80	5	4.65E-8
IZO	200	5	4.76E-8
IZO	300	5	3.70E-7
IZO	450	5	4.30E-7

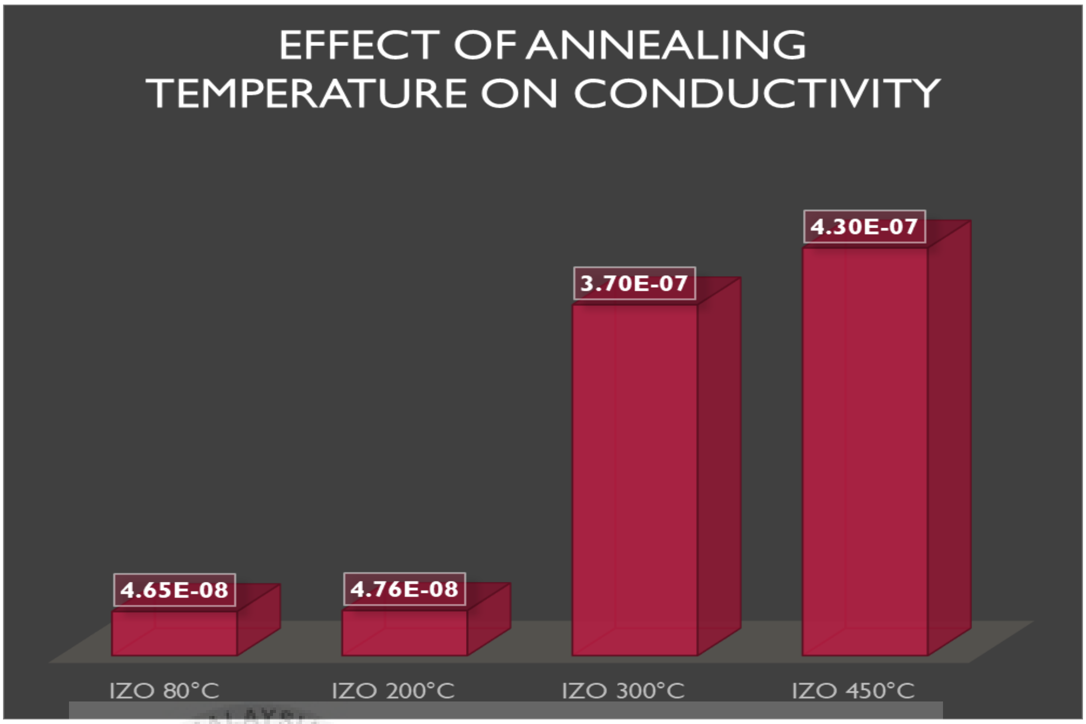

Figure 4.6(b): Bar Chart of Annealing Temperatures on Conductivity

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Synthesis of Indium Zinc Oxide was successfully done by using the sol-gel method to produce IZO powder with different Indium percentages and IZO powder of fixed concentration of Indium concentration at different annealing temperatures.

Zinc oxide is conductive materials but has high resistivity that need to be reduced so that the conductivity flow of Zinc Oxide can be increased. Addition of Indium in the Zinc Oxide is to increase the conductivity of the Zinc Oxide in order to improve the conductivity and decrease the resistivity.

The microstructure of the IZO particle showed that there were changes in the microstructures size as the temperature applied to the IZO particles increased from 80°C to 450°C. The size of IZO particles became smaller with the increase of temperatures.

The electrical conductivity also increased when higher annealing temperatures are applied to the IZO particles during heat treatment. The results prove that Indium increases the conductivity of ZnO and annealing temperatures affects the microstructure and conductivity.

5.2 Recommendations

There are some recommendations that can be improved in the future when conducting this type of project in order to improve the results or make the work flow smooth.

1. The amount of deionized water used as stabilizer when making solution need to be recorded so that the next solution making can be prepared with sufficient amount.
2. EDX test to detect the presence of Indium in the IZO particles need to be detect by using mapping technique compared to spectrum. This is because small ratios of Indium percentages cannot be detected at certain area when the distribution of the Indium is not well distributed.
3. During making solution, Indium need to be weighing right before it is going to put inside the solution. This is because Indium will melt when it was prepared and weighing too early.

5.3 Sustainability

From this study, IZO powder has great potential as conductive filler. The aim of using these materials is used to replace the common EMI shielding material which is metal. Metal is common EMI shielding material, but due to its corrosion and high assembly cost, synthesis of IZO is studied as conductive filler to replace the use of metal.

Besides, the use of IZO as conductive fillers in polymer composite may overcomes the advantages of metal in many ways. Hence, this project can contribute to the sustainability of manufacturing and environment.

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